AUSTRALIAN FEED GRAIN DEMAND

Lynn A. Austin

Economic Research Service
U.S. Department of Agriculture

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ABSTRACT

To provide U.S. grain producers and exporters with information on how to better anticipate competition from Australia's grain exports, this study examines the demand for grains as feed in Australia and how this demand affects Australia's grain export levels. Own price, substitute grain prices, livestock prices, and the livestock inventory were hypothesized to be the major explanatory variables. Based on regression analysis, causal relationships were found between these variables and the consumption of wheat, barley, and sorghum as feed. Oats and corn showed little or no response to price or livestock inventory fluctuations; an alternative hypothesis was proposed—that these grains are grown for on-farm use or insurance against drought. Furthermore, due to the distant and dispersed pattern of production, it is difficult for these grains to compete in the Sydney market. Consequently, the consumption of oats and corn as feed was found to be primarily a function of production.

Keywords: Australia, demand, elasticity, feed grains, grains, grain exports, projections.

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Map is from the 1975-76 Annual Report of the Australian Wheat Board, p. 24.

SUMMARY

Small increases in world wheat prices can result in significantly higher quantities of wheat available for export by Australia, and thus much stronger competition between U.S. and Australian wheat exports.

To provide U.S. grain producers and exporters with information on how to better anticipate the degree of competition from Australia, this study looks at how demand for grain for feed in Australia explains some of the wide year-to-year fluctuations in its grain exports.

Over the past decade, Australia's total grain exports have ranged from 6 to 12 million metric tons annually, with wheat exports varying from 4 to 10 million metric tons. Australia's grain export volume is influenced primarily by the amount of grain produced and consumed domestically. Most of the variability in the quantity consumed occurs in the consumption as feed.

The analysis here shows that demand for wheat for feed in Australia is highly responsive to changes in world wheat prices, world prices of other grains used as feed, and livestock inventories in Australia. For example, a $10-per-ton increase in the world wheat price, together with a $5-per-ton drop in the price of substitute grains, could result in a 500,000-ton drop in the use of wheat as feed in Australia. The 500,000 tons of wheat would most likely be put on the export market.

Demand for barley and sorghum was also found to depend to a large extent on changes in grain prices and livestock inventories, although to a lesser degree than demand for wheat. Still, it was estimated that a small drop in the world barley price could easily result in a 25-percent increase in the amount of barley available for export by Australia.

Demand for oats and corn showed little or no response to price or livestock inventory changes. Corn production in Australia is fairly limited, and exports are minimal.

For wheat, barley, sorghum, and oats, however, Australia is a major world exporter—the fourth largest for the grains combined, even though production accounts for only about 3 percent of world production. Australia's tremendous land resources, suitable climate, high level of technology, and small population permit the country to export a large share of its grain production.

The analysis is based on ordinary least-squares regression analysis. Derived feed demand equations were estimated for wheat, barley, sorghum, oats, and corn. Adjusted coefficients of multiple determination ($\overline{R}^2$) for the final models were over 0.70, except for corn. The own price elasticities, taken at the means, were −2.9 for wheat, −1.2 for barley, and −0.8 for sorghum. The cross-price elasticities, here significant, were 1.4 for wheat and 0.8 for barley. Large livestock inventory elasticities for wheat and barley implied a tendency to feed substantially more of these two grains as inventories increase.

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by
Lynn A. Austin
Agricultural Economist
Foreign Demand and Competition Division
Economic Research Service

INTRODUCTION

Australia accounts for only a small proportion of total world grain production (2.9 percent in 1976), but because of its small population of about 14 million and limited livestock feeding, it has a large excess of production over domestic consumption. Consequently, it is the world's fourth largest exporter of grains (after the United States, Canada, and France) and a key competitor with the United States in many markets.

Australia's grain exports fluctuate widely from year to year, however. Over the past decade, the country's total grain exports have ranged from 6 to 12 million tons annually, with wheat exports varying from 4 to 10 million metric tons.

To make rational policy decisions and economic forecasts, it is critical that U.S. producers, traders, and policymakers know the quantities of grain Australia will offer for export at given prices. To estimate these quantities (that is, the excess supply curve), the domestic demand curve must be approximated. The demand for grain in Australia is derived from four end-uses: food, industry, feed, and seed. This study investigates only the demand for grain as feed. Structural models of the five major grains—wheat, barley, sorghum, oats, and corn[1]—are estimated separately.

Economic History

Nearly 200 years ago, Australia started as a British prison and agricultural colony. Sheep raising and wheat growing were the primary economic activities engaged in by settlers for the first 100 years. The impetus of the two World Wars, however, changed Australia into an industrialized country. By 1970, only 7 percent of the work force was employed in agricultural production. Today, both the agricultural and manufacturing sectors use advanced methods. Also, mining has recently become an important sector. Although manufacturing is primarily for local consumption, most mining and agricultural output is exported.

[1] Hereinafter, these will be referred to as the "major grains," and will include the portion harvested as grain only.

Figure 1


AUSTRALIA
Wheat growing areas
Wheat terminals
Rainfall belts
500 mm
375 mm
250 mm
Northern Territory
Queensland
Western Australia
South Australia
New South Wales
Victoria
Tasmania
Gladstone
Brisbane
Newcastle
Sydney
Geraldton
Fremantle
Kwinana
Bunbury
Albany
Esperance
Thevenard
Port Pirie
Wallaroo
Ardrossan
Port Adelaide
Port Lincoln
Port Giles
Portland
Geelong
N
0 250 500 750 1000 1250 1500
Kilometres

Physical Description

Land and Climate

Australia has a land area of 780 million hectares, about the size of the 48 contiguous U.S. States. Forty percent of Australia lies in the tropics. The country is very low in elevation and relatively flat. The climate is mostly arid, but the littoral areas, where a majority of the population lives, are humid.

Land Use

Roughly two-thirds of Australia's land is used for agriculture (fig. 1); animal grazing and grain production are the most common usage. However, climate conditions, particularly drought, restrict the areas of major crop production to within 500 kilometers of the temperate eastern, southern, and southwestern coasts.

Livestock Industry

Australia is a major producer of livestock products. It is the world's largest exporter of meat and wool and third in exports of dairy products. The cornerstone of these industries is the country's huge range area. In 1975, land devoted to livestock grazing totaled approximately 490 million hectares—nearly two-thirds of the continent's area. Inaccessibility to grain markets and high input-output cost ratios restrict grain consumption in the meat, wool, and dairy product industries. It is primarily the intensive animal production subsector (broilers, layers, and swine) that relies on grains as feed. Chicken, eggs, and pork are mainly produced for the domestic market.

Beef Cattle

Beef cattle are grown in all states, mostly on pasture or range (table 2). The beef herd has grown consistently for the past 25 years. Supplemental grain feeding usually occurs only when there is a drought. At the extreme, it is doubtful that beef growers are equipped for feeding for more than a few weeks. Except for a few operations specialized in producing beef for Japan, feedlotting is not significant.

Sheep

Sheep grown primarily for wool ordinarily receive no supplemental feed in Australia. Since 1965, the sheep herd has been fairly stable. To limit death loss, however, some graziers feed grain during droughts. Lamb and mutton production is centered in the higher rainfall areas of New South Wales and Victoria. Often these herds are raised by farmers who also grow grain. Consequently, the sheep usually graze on the grain stubble in addition to pasture. Furthermore, sheep growers interested in lamb production may set aside a parcel of land seeded to oats for feed. The oats are harvested and fed during periods of slow pasture growth.

Table 1—Exporters of major grains, ranked according to volume of grain exported, 1971/72–1975/76

Rank as exporter	Wheat	Barley	Sorghum	Oats	Corn	Total of five grains
1st	United States	France	United States	United States	United States	United States
2nd	Canada	Canada	Argentina	*Australia*	Argentina	Canada
3rd	France	*Australia*	*Australia*	France	France	France
4th	*Australia*	United States	Thailand	Sweden	South Africa	*Australia*
5th	USSR	United Kingdom	South Africa	Argentina	Thailand	Argentina

Table 2–Number of animals in Australia, by type and by state, as of March 31, 1976

Type of Livestock	Queensland	New South Wales	Victoria	Western Australia	South Australia	Total[1]
			1,000 head			
Beef cattle	10,846	8,510	4,006	2,488	1,683	27,533
Dairy cattle	501	629	1,862	166	208	3,366
Sheep	13,599	53,200	25,395	34,771	17,279	144,244
Swine	409	709	393	260	326	2,097
Poultry	5,829	27,319	8,737	3,617	4,385	49,891

[1] Excluding Tasmania and the Northern Territory.

Source: Australian Bureau of Statistics, *Livestock Statistics*, Canberra, Dec. 14, 1976.

Dairy Cattle

The dairy herd is located primarily on choice pastures in Victoria, New South Wales, and Queensland. The dairy industry in Australia is declining. As with beef cattle, dairy cattle receive grain supplementation only in times of emergency. But because of the compactness of the dairy cattle operation and the responsiveness of dairy cows to grain feed, it is likely that dairy farmers could be flexible as to feed. On the other hand, increasing costs of grain and stable milk prices in recent years have precluded grain feeding to dairy herds. In the 1976 drought, many dairy farmers slaughtered their cows rather than purchase feed for them.

Swine

The swine population in Australia is spread throughout the grain areas roughly in proportion to the human population. After increasing steadily for many years, the swine herd peaked in 1973 and rapidly declined through 1976 because of the profit squeeze. The pork industry has little short-term flexibility in feeding; it must provide a balanced ration to the current herd. In the intermediate term of 1-2 years, however, it is very flexible.

Layers and Broilers

Chickens, whether grown for egg or meat production, are raised near population centers and rely totally on hand or mechanical feeding. Prior to the 1960's, broiler production was mostly a cottage industry (data from before that time are scarce). Since then, however, the output of chicken has doubled. Egg production increased appreciably in 1960-73, but with the high grain prices since 1973, output has leveled off.

LITERATURE REVIEW

Factors affecting retail quantity demanded are generally considered to be the price of the good, the price of substitute goods, the income of consumers, the number of consumers, and tastes and preferences of consumers. Feed grains are intermediate goods or inputs, and consequently, with the assumptions usually associated with profit maximizing, the derived demand for a feed grain can be thought of as being impinged upon by its own price, the price of substitutes, and the price of the final product. The following review covers other studies which estimate the demand for grains as feed. Also, a few studies dealing with the unique problems of this paper are reviewed.

Gruen *et al.* *(4)*[2] suggested that seasonal conditions (mainly droughts in grazing areas), the increase in the size of the broiler industry, the movement of pig production to grain districts, the gains in feed conversion ratios in the egg and broiler industries, and "economic factors" (given as the ratio of feed price to output price) should be used to estimate the demand for feed grains in Australia. Unfortunately, the amount of feed by type of livestock was not available and the model based on aggregate animal numbers proved unreliable.

Regier and Goolsby (*6*) carried out a series of calculations based on the estimated per capita consumption of meat, per capita consumption of food grains, and the grain/meat ratio to project Australian demand for feed grain in 1980. Assumptions were made about future income, population, prices, and income elasticities of demand for meat. The quantity estimated for Oceania was 1.061 million tons for 1980. In 1975/76 (December-November), however, about 2.1 million tons of grain were consumed as domestic feed in Australia.

Possibly the most scrupulous research on demand for feed grain in Australia was carried out by Bain (*1*) at Monash University in Melbourne. He attempted to estimate relationships between the consumption and prices of various grains in Australia and to isolate the major factors causing shifts in the demand for feed grains. Because of "specification difficulties and problems of estimation," corn and grain sorghum models were not estimated. The equations for feed wheat, barley, and oats were incomplete. Pastoral conditions and the growth of intensive livestock production were found to be the only significant factors influencing demand for feed wheat. Demand for oats responded only to its own price, while barley demand was a function of a time trend. Bain offered convincing arguments for rejecting the null hypotheses, despite the statistics. He criticized the available data as not being rich enough in independent variation to provide reliable estimates for his analysis.

Egbert and Reutlinger (*2*), in their long-term livestock/feed sector model for the United States, specified the demand for feed as a function of livestock production units, the price of livestock, and the prices of feed grains and hay. The livestock price was used in a ratio to the feed grain price in the estimation to yield a coefficient of determination (R^2) of 0.96.

Motha *et al.* *(5)* pointed out that variability in the consumption of grains feed in Australia is due to weather fluctuations. They emphasized the substitutability of wheat for traditional feed grains, as reflected in the similar movements of their prices. Caution was advised in the use of domestic prices when large quantities of both feed grains and meat were being exported.

In 1972, Friend *et al.* *(3)* modified previous studies to project domestic utilization of feed grain in Australia in 1975. Gruen's errors were explained and new predictors were projected. Friend postulated that domestic feed

[2]Italicized numbers in parentheses refer to literature listed at the end of this report.

grain use would increase by about 10 percent, largely because of a surge in beef feedlot feeding that was occurring at that time. Actually, exports increased substantially between 1971 and 1975, but domestic consumption decreased by some 25 percent.

One of the recent outstanding efforts to estimate the demand for feed grains is attributable to Womack (7). He specified a model for the United States in which the quantity demanded of each feed grain (corn, oats, sorghum, and barley) was dependent upon its own price, the price of high-protein feeds, the livestock output price, the price of competing feed grains, the livestock input price, inventories, and technology. He discussed the effects of short- and long-term decisions made by livestock producers on feed grain demand. Womack concluded that the demand for corn was not cross-price elastic with oats, sorghum, barley, and the minor grains. The reasoning was that, although these grains are biologically substitutable, the locational advantage of corn in the livestock production region precludes competition from grains produced in other regions, except in cases of extreme price-per-nutrient disparities. The statistics were significant at or above the 95-percent level, with adjusted coefficients of determination ($\overline{R}^2$) ranging from 0.84 to 0.98. However, each of the minor grains were found to be significantly cross-price responsive, indicating the superiority that corn maintains in livestock feeding rations.

DESCRIPTIVE ANALYSIS

Wheat, barley, oats, sorghum, and corn are grown in the five major Australian states (table 3). Except for small, very specialized plantings, cultivation is carried out under nonirrigated or dryland conditions. Because rainfall during the growing season is near the minimum required for plant growth, slight reductions in precipitation cause significant decreases in yields. Consequently, grain output in Australia is highly variable.

Wheat, barley, and oats are grown in rotation with pasture grasses and legumes. As a result, most grain farmers also raise grazing animals, usually beef cattle and sheep. Unrecorded quantities of grain are stored on the farm and later fed to livestock (which complicates the process of estimating domestic demand).

Wheat

Wheat is the most extensively grown crop in Australia. Annual production during 1972-76 averaged 9.0 million tons. Upon harvest, farmers set aside what they need for seed and feed and transport the remainder to the nearest grain silo. Producers of wheat are legally required to sell their grain to the quasi-governmental Australian Wheat Board (AWB).

The AWB sells the wheat mainly to domestic flour mills, feed manufacturers, and foreign buyers. Every year, the Board sets a domestic wholesale ("home consumption") price based on the cost of production which prevailed in the previous marketing season (December-November). It guarantees sale of unlimited quantities to domestic users at that price. Most Australian wheat, however, is exported at world market prices. Two-thirds of the 1975/76 crop was exported.

The domestic use of wheat as flour has been closely related to population over the past 25 years. As feed, however, wheat is used during periods of drought because of the unlimited supply guaranteed by the AWB at the fixed domestic wholesale price. Thus, when feed crops (pasture and coarse grains) fail because of drought (app. I), their market-determined prices rise relative to the price of wheat, and consumption of wheat as feed rises.

The actual quantity of wheat consumed as feed from 1960/61 to 1975/76 is plotted in figure 2, along with estimated and projected quantities (which are explained later). The sample period used for statistical analysis was only 1960/61 to 1972/73, however, in order to allow three observations (1973/74-1975/76) for validating the model. Variation from the mean of 721,400 tons (table 4) of the 13-year sample was substantial (*C. V.* = 45.8 percent).[3] The time trend was significant ($\bar{R}^2$ = 0.415) (table 5). The extreme low of the sample occurred in 1962/63 and the extreme high of the sample was recorded in 1972/73.

[3]C.V. is the coefficient of variation $(\hat{\sigma}/\hat{\mu}) \bullet 100$, where $\hat{\sigma}$ is the estimated standard deviation and $\hat{\mu}$ is the estimated mean.

Table 3—Grain area in Australia, by state and percent of total area in grains and pastureland, 1975

Type of grain	Western Australia	New South Wales	South Australia	Victoria	Queensland	Total[1]
			1,000 hectares			
Wheat	3,166	2,774	959	1,073	579	8,551
Barley	419	486	832	344	235	2,316
Oats	320	289	119	243	12	983
Grain sorghum	2	168	–	–	334	504
Corn	–	20	–	–	31	52
Total major grains	3,907	3,737	1,910	1,661	1,191	12,406
			Percent			
Percent of area in grains	1.6	4.7	1.9	7.3	0.7	1.6
Percent of area in pastures and grazing land	63.4	80.7	62.5	58.4	88.9	63.4

[1]Excludes Tasmania and the Northern Territory.

Source: Australian Bureau of Statistics, *Crop and Fruit Statistics*, Canberra, Oct. 11, 1976.

Table 4—Descriptive statistics, consumption of grain as feed, Australia, 1960/61–1972/73

Type of grain	Mean	Standard deviation	Coefficient of variation	Extremes	
				Low	High
	1,000 metric tons		Percent	1,000 metric tons	
Wheat	721.4	330.4	45.8	398	1,556
Barley	434.9	185.4	42.7	193	769
Sorghum	300.8	163.6	54.4	193	780
Oats	656.1	217.0	33.1	298	1,047
Corn	129.9	21.9	16.7	79	150

Table 5—Time trends, consumption of grains as feed, Australia, 1960/61–1972/73

Type of grain	Estimated trend coefficient[1]	Coefficient of variation, in percent	Adjusted coefficient of multiple determination
Wheat	57.758	35.0	0.415
Barley	40.269	23.9	0.686
Sorghum	19.434	50.3	0.143
Oats	17.841	32.7	0.021
Corn	-2.049	16.2	0.057

[1]Linear trend, using 1960, 1961, etc., as the independent variable, estimated by ordinary least-squares regression.

Oats

Historically (before the 1930's) significant as a horse feed, oats are becoming less prominent as feed in Australia. The area in production declined by one-third between 1960 and 1975, making oats the only major grain to show a decline in area in that period. It was still the third largest grain in terms of production during the 1975 season, however.

As would be expected of a traditional draft animal feed, oats are produced in every state. But because of their current use as sheep feed, they are proportionally more abundant in states with large sheep populations.

There are three oat marketing boards—one in Western Australia, one in Victoria, and another in New South Wales. Free trade between the states prevails, however. Oats are produced primarily for domestic feed use. In 1975, only one-third of oat production was exported.

As can be seen in figure 5, the consumption of oats as feed has fluctuated wildly. There was no significant trend in the sample ($\bar{R}^2$ = 0.020). The extreme high of the sample was recorded in 1966/67. The extreme low occurred in 1967/68 and may be attributed to the drought-reduced oat crop.

Corn

Corn is by far the least important of the major grains in Australia. Only a small area in the coastal plain of Queensland and New South Wales has the required hot and wet climate with an accessible location. Only 53,000 hectares of corn were harvested in 1975.

One marketing board, the Atherton Tableland Maize Marketing Board, is in operation and handles most of the production. Exports are negligible.

Figure 6 shows the constancy of domestic corn feed use. No significant trend was found in the sample ($\bar{R}^2$ = 0.057).

Barley

Similar to but more drought-resistant than wheat, barley is grown primarily in the drier grain areas in South and Western Australia. It is an important auxiliary grain in wheat areas, however. When the wheat planting season is unusually dry, farmers often switch to barley at the last moment to increase their chances of a harvestable crop.

In contrast to the national compulsory marketing board for wheat, there are four voluntary marketing boards for barley (Western Australia, New South Wales, Queensland, and combined South Australia and Victoria). Owing to a cherished constitutional article, free trade is guaranteed between the Australian states, effectively curbing the control of any one of the boards.

Although most barley is exported (two-thirds of the 1975/76 crop), several thousand tons are used internally for malting[4] and feed. Like other feed concentrates, it is used principally in swine and poultry rations.

The consumption of barley as feed from 1960/61 to 1975/76 generally increased (fig. 3). The average rate of increase for the sample was 40,000 tons per annum. The strong trend signifies that the causal factors of barley demand as feed are related to time.

[4] Australia has the third largest per capita beer consumption in the world.

Sorghum

Unlike wheat or barley, which have been grown widely in Australia for nearly 200 years, sorghum has become popular only recently. Prior to 1950, commercial production was negligible.

Tremendous improvements have been made in the yields and marketable characteristics of sorghum over the past two decades. Additionally, sorghum, with feeding qualities similar to corn, can be grown in areas that are marginal for corn. In this respect, sorghum is to corn what barley is to wheat. Therefore, sorghum is cultivated only in the moderate rainfall areas of Queensland and New South Wales.

There are three sorghum boards–two in Queensland and one in New South Wales. Free interstate trade precludes a marketing monopoly, however. Only in the past 5 years has sorghum become an important export.

The consumption of sorghum as feed for 1960/61-1975/76 is shown in figure 4. Consumption was relatively stable early in the sample period, then increased slightly. The average rate of increase in the sample was 19,000 tons per annum. Noteworthy was 1970/71–actual consumption was twice that of the trend value. A possible explanation is that poultry production increased 25 percent during that year and sorghum output doubled.

INTEGRATIVE ANALYSIS

Hypothesis

This section documents the estimated relationships between consumption of each of the five major grains as feed and the price of the grain itself, the price of substitutes, the price of livestock, and livestock inventories. The behavioral model used is postulated as follows:

$$Y_i = f(X_{1i}, X_{2i}, X_3, X_4) \qquad (1)$$

where Y_i = quantity demanded of the *i*-th feed grain.
X_{1i} = price of the *i*-th grain (own price).
X_{2i} = price of substitute grains.
X_3 = price of livestock.
X_4 = inventory of livestock.

The anticipated relationships are inverse for X_{1i} and direct for X_{2i}, X_3, and X_4. It is further anticipated that the equations are linear and that the effects of the independent variables are accomplished within each year (no lags). Other factors that impinge upon domestic consumption of grains as feed are assumed constant.

The hypothesized behavioral equations (1) are arranged in a fashion suitable for estimation by means of ordinary least-squares (OLS) regression. The relationships are specified as follows:

$$Y_i = B_{oi}X_o + B_{1i}X_{2i} + B_{1i}X_{2i} + B_{3i}X_3 + B_{4i}X_4 + u_i \qquad (2)$$

where Y_i = quantity demanded of grain *i*.
X_o = constant term = 1.
X_{1i} = price of grain *i*.
X_{2i} = price of grains that substitute for *i*.
X_3 = price of livestock.
X_4 = inventory of livestock.
B = coefficients.
u = disturbance term.
i = (*w*)heat, (*b*)arley, (*s*)orghum, (*o*)ats, (*c*)orn.

Data

Data for the regression were compiled from various Australian sources (see apps. II and III). The observations were for 1960/61 to 1972/73. The definitions of the price of substitute grains, the price of livestock, and the inventory of livestock are as follows:

1. The price of substitutes is a weighted average price, with average consumption over the sample as weights for each grain. All grains were assumed to substitute for each other.

2. The price of livestock is a weighted average price, with pork and poultry production as weights.

3. The inventory of livestock is a weighted inventory, with weights in proportion to the estimated consumption of feed by type of animal.

Correlation matrixes of these variables are in appendix IV.

Procedure

The ordinary least squares regressions were run. If any estimated coefficient had a perverse (unexpected) sign or a t-value less than 1.0, a respecification was executed, eliminating one variable. The following priorities of variable elimination are listed in order of first to last eliminated:

X_3 = livestock price.

X_{2_i} = substitute price.

X_4 = livestock inventory.

X_{1_i} = own price.

The estimated equations for wheat and barley explained reasonably well ($\bar{R}^2$ = 0.767 and 0.700, respectively) the relationships between the above mentioned variables and feed consumption of the two grains. For sorghum, oats, and corn, however, the coefficients of multiple determination were 0.287, 0.043, and 0.030–implying that factors other than the specified variables were important. In the following section, the wheat and barley models are discussed as indicative of the expected relationships. An attempt is made to explain residuals which are more than 25 percent of the mean. Rationalizations are given for the respecification of the other three models and the recalculated parameters are elaborated.

The ability of the model to predict is tested by extrapolating through 1973/74, 1974/75, and 1975/76. The reliability of the estimated coefficients is analyzed by incrementally including the three latest observations in the sample and reestimating the parameters (app. V).

Results

Wheat

The estimated complete model for wheat showed all coefficients significant, correct signs, and a reasonable $\bar{R}^2$.

$$Y_{w} = -1452.76 - \underset{(2.109)}{0.36448} X_{1w} + \underset{(2.766)}{0.20296} X_{2w} + \underset{(1.027)}{11.7093} X_3 + \underset{(5.783)}{1.21103} X_4 \quad (3)$$
(t)

$n = 13 \qquad S.E. = 159.6 \qquad D.W. = 1.750 \qquad \bar{R}^2 = 0.7666$

The estimated values are plotted in figure 2. The equation raises the explained variation by 35.18 percentage points from simple trend analysis. Equation (3) can be interpreted as follows:

1. A \$1-per-ton increase in the price of wheat will bring about a 36,448-ton decrease in the consumption of wheat as feed, or, in more technical terms, the price elasticity of demand for wheat as feed is −2.859 at the sample means and −1.334 at 1972/73 values.

2. A \$1-per-ton increase in the price of substitute grains will result in a 20,296-ton increase in the consumption of wheat as feed, or, the cross-price elasticity of demand for wheat as feed is 1.447 at the means and 0.910 at 1972/73 values.

3. A one-unit increase in the livestock price index will effect a 11,709-ton increase in the consumption of wheat as feed, or, the livestock price elasticity of demand for wheat as feed is 1.604 at the means and 0.831 at 1972/73 values.

4. A one-million-unit increase in the livestock inventory will effect a 1,211-ton increase in the consumption of wheat as feed, or, the livestock inventory elasticity of demand for wheat as feed is 2.817 at the sample means and 1.625 at 1972/73 values.

The estimated relationships were not considered extreme, but the elasticities (at the means) of own price and the livestock inventory appeared high. The only observation not adequately predicted was that for 1960/61. This anomaly remains unexplained. The equation predicted the direction of seven of eight major changes within the data.[5]

[5] "Major" is defined as a single-year change of one standard deviation or more.

Extrapolating beyond the sample for validation of the model yielded the following results:

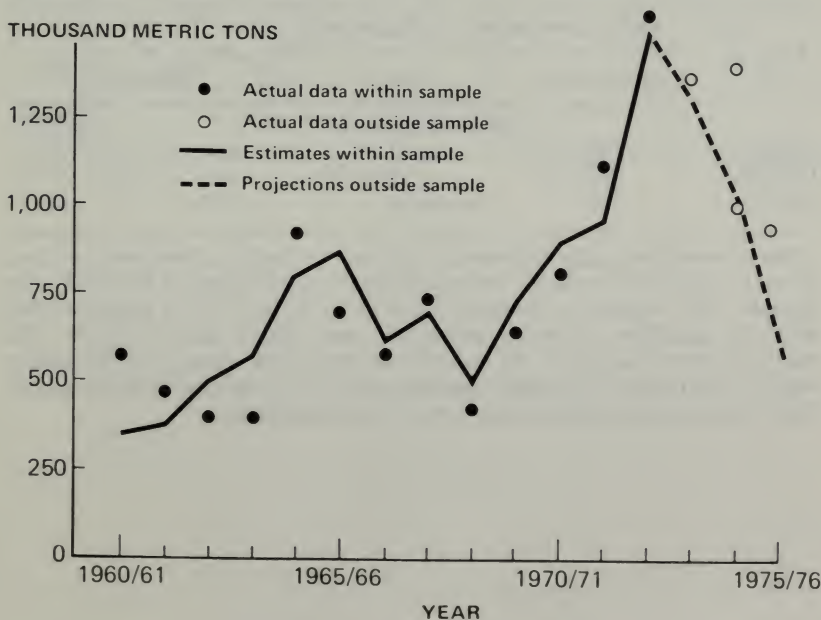
Year	Wheat consumption as feed: Projected	Wheat consumption as feed: Actual	Difference	
	1,000 metric tons			Percent
1973/74	1,317	1,369	-52	-3.9
1974/75	1,032	1,394	-362	-26.0
1975/76	558	937	-379	-40.4

To test for structural change, the actual 1973/74 observation was added to the sample data and the coefficients were reestimated. The new estimated values were not significantly different from those of the initial data set, except for the livestock price coefficient (see app. V). The standard error on this coefficient exceeded the value of the coefficient resulting in a *t*-value of less than 1.0. The same outcome was observed when 1974/75 and 1975/76 observations were included incrementally.

Therefore, the current model must reflect this drop in the price elasticity. The following equation—calculated using the means of the estimated parameters for the samples of 1960/61-1973/74 (n = 14), 1960/61-1974/75 (n = 15), and 1960/61-1975/76 (n = 16)—provides a current description of the structure:

$$Y_w = -976.833 - 0.32068X_{1_w} + 0.20879X_{2_w} + 4.8952X_3 + 1.61124X_4 \quad (3a)$$

Figure 2
Wheat consumption as feed in Australia, actual, estimated, and projected, 1960/61-1975/76



Barley

The estimated model for barley produced a negative sign on the livestock price coefficient, and the coefficient on the price of substitutes was insignificant. Eliminating the livestock price variable resulted in a significant t-statistic on the price of substitutes. The emergent equation is given below and the estimated values are plotted in figure 3:

$$Y_{b(t)} = -673.34 - \underset{(2.041)}{0.13025X_{1b}} + \underset{(0.999)}{0.05950X_{2b}} + \underset{(5.013)}{0.77172X_4} \qquad (4)$$

$n = 13$ $\quad S.E. = 101.4$ $\quad D.W. = 3.000$ $\quad \bar{R}^2 = 0.7024$

The gain in $\bar{R}^2$ over trend was only 1.62 percentage points.

The estimated coefficients in equation (4) can be interpreted in a similar manner as was done above for wheat. The elasticities are as follows:

	X_{1b}	X_{2b}	X_4
Means	-1.198	0.770	2.978
1972/73	-1.269	0.658	2.984

These estimated relationships were considered reasonable, although a slightly larger cross-price elasticity and a much smaller livestock inventory elasticity were expected. The low cross-price elasticity implies that barley is not readily substituted, and the high livestock inventory elasticity implies that the quantity of barley in rations is increasing rapidly.

There are poorly explained observations for 1966/67 and 1967/68, but the latter may be the result of the drought, when prices of substitute grains peaked.

Extrapolating, the following projections were made:

Year	Barley consumption as feed: Projections	Barley consumption as feed: Actual	Difference	
	1,000 metric tons			Percent
1973/74	493	642	-149	-23.2
1974/75	228	334	-106	-31.7
1975/76	220	695	-475	-68.3

The correlation (multicollinearity) between the price of livestock and own price ($r = 0.5978$) precluded the measurement of the effect of livestock price changes. The increase in livestock prices in 1973/74-1975/76 would explain why the quantities of barley consumed were higher than predicted. This model predicted correctly the direction of the major changes in the sample, and did not predict *any* major changes that did not occur within the sample. The extrapolation predicted only one of the three changes.

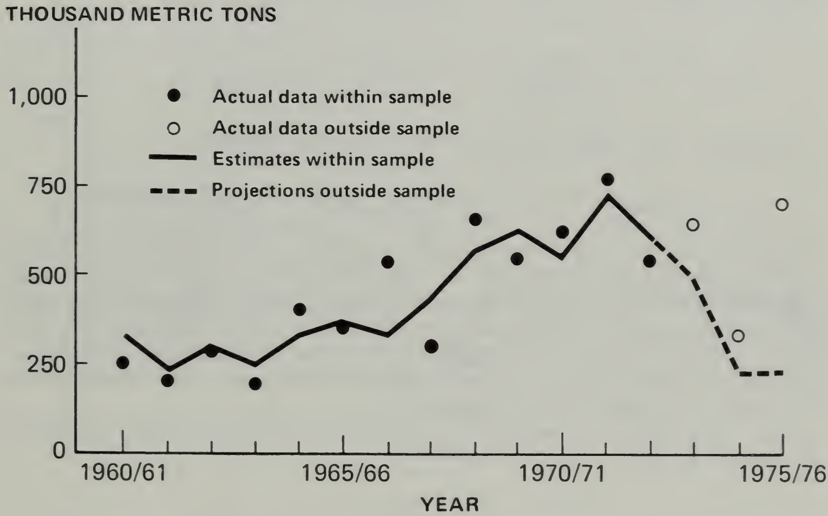
Upon reestimating the parameters with the incrementally larger samples (1960/61-1973/74, 1960/61-1974/75, and 1960/61-1975/76), it became apparent that—aside from the 1960/61-1974/75 sample, which suffered from severe multicollinearity—there were no significant shifts in the value of the coefficients of equation (4). However, the missing variable, livestock price, did show the proper sign (albeit with low t-values) in both the 1960/61-1973/74 and 1960/61-1975/76 samples.

Consequently, it was concluded that a structural shift did take place in 1973/74, and for predicting, the new coefficients should be the average of the stable coefficients estimated from the 1960/61-1973/74 and 1960/61-1975/76 samples—that is:

$$Y_b = -1091.25 - 0.12525X_{1_b} + 0.08301X_{2_b} + 2.1100X_3 + 0.80695X_4 \quad \text{(4a)}$$

Figure 3

Barley consumption as feed in Australia, actual, estimated, and projected, 1960/61-1975/76



Sorghum

The estimated complete sorghum equation yielded questionable coefficients. The sign on the price of the substitutes coefficient was perverse, and the *t*-statistic was not significant on the coefficient estimated for the price of livestock. Eliminating the price of livestock variable and reestimating did not change the sign on the substitute grain price coefficient, and in the third specification it was dropped. The resulting equation was very poor, with an $\bar{R}^2$ of 0.2837.

A check of the residuals showed 7 outside of the 25-percent-of-the-mean boundary. In 1969/70 and 1970/71, precipitation in Australia was not adequate to plant wheat, so many farmers delayed and then planted sorghum. A program to stimulate sorghum growing had been under way since 1967 by a joint Australian-Japanese group. The marketing of the grain had also been improved. So the combination of a drought and other pressures led to a doubling of output in 1969 and again in 1970. Because most of the feed sorghum was sold in Queensland and northern New South Wales (possibly on contract), the Sydney price did not reflect the market conditions. For this analysis, it was felt that the sorghum equation needed to be respecified with a zero-one dummy to correct for the 2 irregular years.

The respecified equation was

$$Y_{s(t)} = \underset{}{83.4056} - \underset{(1.470)}{0.07517X_{1_s}} + \underset{(1.692)}{0.23804X_4} + \underset{(5.318)}{340.261D} \tag{5}$$

where D = 1 for 1969/70 and 1970/71 and zero elsewhere.

$n = 13$ $\quad S.E. = 71.7$ $\quad D.W. = 2.386$ $\quad \bar{R}^2 = 0.8079$

The statistics are very reasonable. The estimated values are plotted in figure 4. The equation predicted four of five major changes in the sample. The remaining outliers of concern were 1967/68 and 1968/69. Because of drought and relatively high prices for substitute grains in 1967/68, actual consumption of sorghum for feed use was higher than that predicted by the equation. In 1968/69, pasture conditions were the best in 10 years, which explains why the equation overestimated consumption.

The coefficients of equation (5) can be interpreted as was done for wheat. The elasticities are:

	X_{1_s}	X_4
Means	-0.779	1.328
1972/73	-1.073	1.757

Extrapolating, the following projections were made:

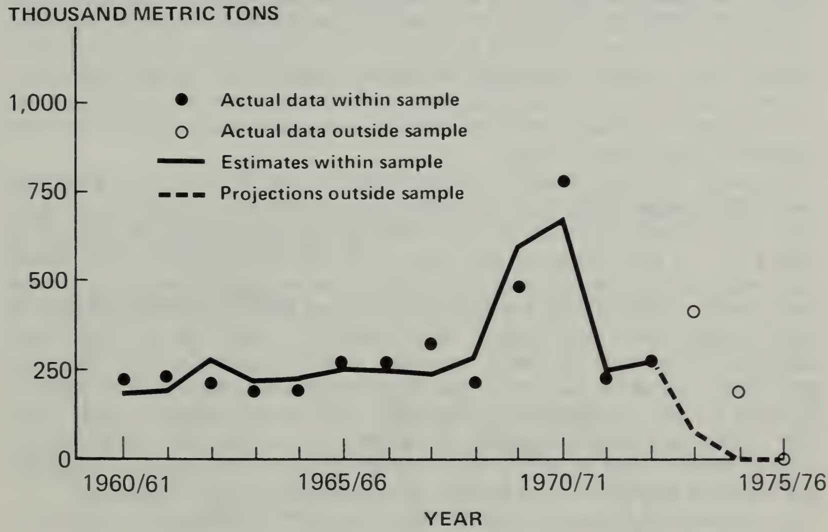
Year	Sorghum consumption as feed: Projected	Sorghum consumption as feed: Actual	Difference	
	1,000 metric tons			Percent
1973/74	78	419	-341	81.4
1974/75	0	187	-187	——
1975/76	0	0	0	0

The large grain price increases in 1973/74 and forward were partly nominal. Relative to prices of substitutes, the price of sorghum increased only about 40 percent in real terms, compared with 58 percent in nominal terms. The price in the model was not deflated.

Adding the 1973/74-1975/76 observations incrementally led to unreliable estimators of the own-price coefficient. The livestock inventory and dummy variable coefficients were stable. Equation (5) appears to be the most reliable specification.

Figure 4

Sorghum consumption as feed in Australia, actual, estimated, and projected, 1960/61-1975/76



Oats

The complete model for oats yielded nonsignificant coefficients on all variables. Removing the livestock price variable led to no substantial improvement in t-tests. Upon removing the price of substitutes, the t-statistics on own price and livestock inventory exceeded 1.0. However, the $\bar{R}^2$ was only 0.431, indicating a need for further investigation into factors affecting oat feeding.

In Australia, oats are grown mostly on farms which also raise livestock, for two reasons: (1) Oats are used as a cover crop in a rotation such as wheat/oats/alfalfa (or clover)/fallow. They shelter the young alfalfa and serve as a natural herbicide by aggressively competing with weeds. Once the oats are cut, the alfalfa dominates and is grazed or cut for hay. (2) Oats are used as an insurance feed, particularly for sheep. If a drought occurs, pasture grass production falls and the sheep may lose weight. The recouping of this weight loss (compensatory gain) is very costly, plus flock mortality is increased. Droughts are frequent and unpredictable in Australia. So, instead of risking large production losses, graziers typically set aside a portion of land for oats to be harvested and stored for drought feed. If no drought occurs, the grain is fed as a "topping" for lambs before marketing, and as an extra boost to help ewes during pregnancy and nursing.

The result of these unusual circumstances is that farmers who grow and feed oats respond neither to oat prices nor to the number of livestock on their farms. Only if prices were to change radically would the farmer be willing to sell this insurance feed. Also, because pastures are neatly fenced into large tracts, it would require a sizable change in herd inventory to warrant adding or eliminating a standard 30-hectare field (producing roughly 30 tons—enough for 1,600 sheep). Area planted to oats has not fluctuated markedly in the past 10 years. In short, many oat growers feed what they grow (only about 24 percent of the crop is exported) regardless of price. If the yield is good, the sheep get a little extra oats during the dry season; if not, they might lose a little weight. Therefore, the factor that influences the consumption of oats as feed is primarily the quantity produced. This variable was included along with own price in a respecification of the oat model.

The respecified equation is given below and estimated values are plotted in figure 5.

$$\underset{(t)}{Y_o} = 252.65 - \underset{(1.955)}{0.04040X_{1_o}} + \underset{(6.359)}{0.49740P_o} \qquad (6)$$

where P_o = production of oats in thousands of tons.

$n = 13 \qquad S.E. = 86.1 \qquad D.W. = 1.022 \qquad \bar{R}^2 = 0.8428$

Price was significant but the elasticity was expectedly low (−0.347 at the mean). The gain over trend analysis as measured by the $\bar{R}^2$ was 82.19 percentage points. There were no significant outliers. The equation predicted eight of nine major changes in consumption in the sample.

Extrapolating, the following projections were made:

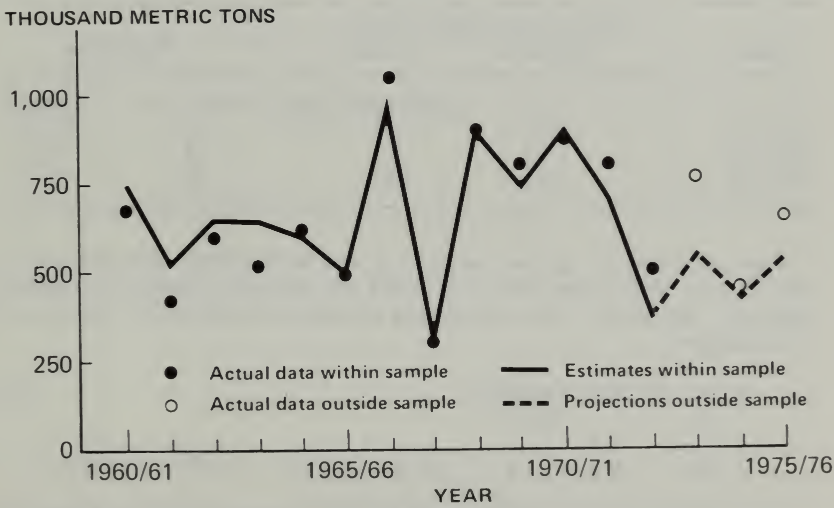
Year	Oat consumption as feed		Difference	
	Projected	Actual		
	1,000-metric tons			Percent
1973/74	555	762	207	27.2
1974/75	421	458	37	8.1
1975/76	538	645	107	16.6

Upon including the above years as observations and recalculating the parameters, no significant changes were found.

The average of the four samples, with n = 13, 14, 15, and 16, and the recommended predictive equation was:

$$Y_o = 262.12 - 0.03704X_{1_o} + 0.48482P_o \qquad (6a)$$

Figure 5
Oat consumption as feed in Australia, actual, estimated, and projected, 1960/61-1975/76



Corn

The complete model for corn resulted in perverse signs on all coefficients except own price. Upon reducing the model one step at a time to get proper signs and significant coefficients, the resultant equation involved only own price and the $\bar{R}^2$ was 0.0299.

It was assumed that corn, like oats, are primarily consumed locally. It should be noted, however, that unlike oats, consumption of corn as feed has not fluctuated noticeably in the past 15 years.

The resultant equation was:

$$Y_{c(t)} = 30.292 + \underset{(3.212)}{0.5666P_c} \tag{7}$$

where P_c = production of corn in thousands of tons.

$n = 13$ $\quad$ $S.E. = 16.3$ $\quad$ $D.W. = 0.553$ $\quad$ $\bar{R}^2 = 0.4372$

Although the $\bar{R}^2$ was low, the relative lack of variability of corn use as feed did not warrant further investigation. This equation is a considerable improvement on trend, which had an $\bar{R}^2$ = 0.0569. The estimated values are plotted in figure 6.

Extrapolating, the following projections were made:

Year	Corn consumption as feed		Difference	
	Projected	Actual		
	1,000 metric tons			Percent
1973/74	109	84	25	29.8
1974/75	90	51	39	76.5
1975/76	106	66	40	60.6

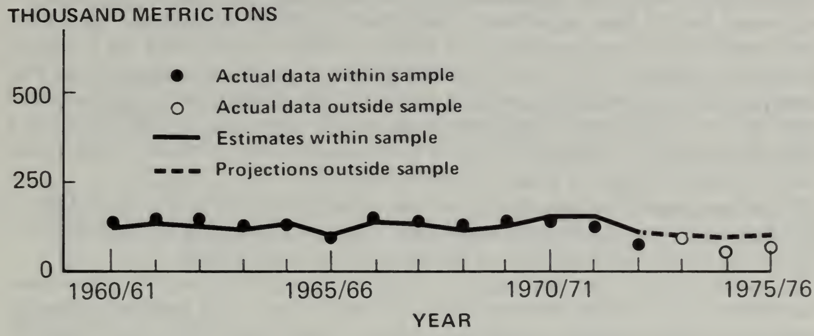
Upon including the above observations and reestimating, both the percentage of corn production used as feed and the amount of variation explained increased significantly. For predicting purposes the following equation is recommended:

$$Y_{c(t)} = -24.386 + \underset{(5.742)}{0.85619P_c} \tag{7a}$$

$n = 16$ $\quad$ $S.E. = 18.4$ $\quad$ $D.W. = 0.582$ $\quad$ $\bar{R}^2 = 0.6807$

There appears to be a trend toward a larger proportion of corn being used in livestock feeding in Australia.

Figure 6
Corn consumption as feed in Australia, actual, estimated, and projected, 1960/61-1975/76



CONCLUSIONS

In this analysis of the demand for grain as feed in Australia, the equation for wheat consumption as feed was more responsive to the specified determinants than were the equations for barley, sorghum, oats, and corn, as evidenced by the four significant coefficients and high elasticities for wheat. The extraordinary responsiveness of wheat as feed to prices and the livestock inventory indicates that a very volatile situation exists *vis-a-vis* exports. For example, an increase in the price of wheat of $10 per ton, and a concomitant drop in the price of a substitute grain of $5 per ton, would result in a 500,000-ton drop in the use of wheat for domestic feed, with the likely result that the 500,000 tons of wheat would be exported.

Therefore, small changes in any of the determinant variables, according to the above analysis, could have significant effects on the quantity of wheat for sale in the world, with obvious consequences for world prices.

To a lesser degree, but still highly volatile, is barley. Whereas the Australians themselves may control the domestic price and, hence, to a certain degree the exports of wheat, barley is sold on a more or less free market (although the wheat price does influence barley use via the substitution effect). Changes in world prices of barley could easily result in a 25-percent change in the quantity of barley offered for export by Australia.

Recent increases in the cost/price ratios in the pork and poultry industries in Australia have caused a decline in the livestock inventory – so much, in fact, that the consumption of sorghum as feed in 1975/76 was zero. However, if the price of beef, mutton, and lamb increases, the substitution of pork and chicken in the Australian diet would likely occur, causing a return to sorghum feeding. This, in turn, would cause a reduction in sorghum exports.

Only to the extent that weather affects yields and production of oats can any change be expected in the use of oats as feed. However, the trend has been to less area devoted to oats each year, probably because of the relative lucrativeness of alternative uses of the land. Small variability in the quantity exported is likely.

Equally unimportant will be competition from the limited corn industry. The production forthcoming from the extremely limited suitable land will most likely be consumed in Australia.

The conclusions of this study generally support those of Gruen et al. *(4)* regarding the effects of broiler industry size (livestock inventory) and the feed output price ratio on grain consumption. The seasonal conditions suggested in Gruen's study are likely reflected in the own price and the price of substitutes in the models used in this study. No specific parameters were estimated by Gruen, however, for comparison. Broad range projections for 1975 were accurate for wheat feed use only.

The results of the current report also partially concur with Bain *(1)* regarding the wheat, barley, and oat demand equations, but his equations showed a dearth of economic relationships by comparison.

Because of the difference between the livestock industries of the United States and Australia, Womack's *(7)* conclusions were replete with the influences of corn and fed-beef, which are incongruous with Australia's wheat and barley-fed pork and broiler production. However, the regional influence that contributes to feed corn independence found in Womack's study is analogous to the oat and corn independence found in this study.

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APPENDIX I – DROUGHT INDEX[1]

Year	Type of year	
	July-June	December-November
1960/61	97	96
1961/62	94	99
1962/63	105	99
1963/64	91	98
1964/65	107	116
1965/66	91	98
1966/67	128	118
1967/68	103	108
1968/69	115	103
1969/70	87	87
1970/71	88	96
1971/72	106	105
1972/73	104	108
1973/74	114	104
1974/75	90	88
1975/76	84	92
1976/77	104	104

[1]The annual average weight (July-June years) of fleece shorn was regressed over time (1950, 1951, etc.). The residuals were then indexed with 0 = 100; positive residuals – i.e., above average weather years – are assigned numbers proportionally *below* 100 to reflect low prices; conversely, negative residuals are treated as indicators of high pasture prices. The Dec.-Nov. index is estimated proportionally from the July-June index.

APPENDIX II–DESCRIPTION OF VARIABLES AND DATA SOURCES

Endogenous Variables

Y_w Consumption of wheat as feed, Dec.-Nov. years, 1,000 tons, derived from production less seed use less deliveries to the AWB, plus amount sold as stock feed by AWB. Seed use was estimated for 1960/61-1968/69 using the wheat area and a seeding rate of 64 kilograms per hectare. (On-farm feed use data have been published since 1969/70.)

Y_b Consumption of barley as feed, Dec.-Nov. years, 1,000 tons.

Y_s Consumption of sorghum as feed, July-June years, 1,000 tons.

Y_o Consumption of oats as feed, Dec.-Nov. years, 1,000 tons.

Y_c Consumption of corn as feed, July-June years, 1,000 tons.

Exogenous Variables

Grain Prices

X_{1w} Home consumption price for wheat as feed, cents per ton, Dec.-Nov. years.

X_{1b} Price of bulk cape barley, Alexandria market (Sydney), cents per ton, average of monthly quotations, Dec.-Nov. years.

X_{1s} Price of bulk sorghum, Alexandria market (Sydney), cents per ton, average of monthly quotations, July-June years.

X_{1o} Price of bulk feed oats, Alexandria market (Sydney), cents per ton, average of monthly quotations, Dec.-Nov. years.

X_{1c} Price of bulk corn, Alexandria market (Sydney), cents per ton, average of monthly quotations, July-June years.

Price of Substitutes

$$X_{2i} = \Sigma \; \bar{Y}_j X_{ij}$$

where i, j = wheat, barley, sorghum, oats, corn.
$j \neq i$ (for i = wheat, barley, or oats, all X_i are on Dec.-Nov. years; for i = sorghum or corn, all X_i are on July-June years)

Price of Livestock

$$X_3 = (AB + CD)/(B + D)$$

where A = index of pig prices, July-June years.
B = average annual pork production, 1965/66-1974/75 = 93,000 tons.
C = index of poultry prices, July-June years.
D = average annual poultry production, 1965/66-1974/75 = 311,000 tons.

Inventory of Livestock

$$X_4 = 1.0A + 3.0B + 5.4C + 256.2D + 1.0E + 1.0F.$$

The following inventories and weights are used:

	Weight[1]
A = Beef cattle inventory, as of Mar. 31, million head.	1.0
B = Dairy cattle inventory, as of Mar. 31, million head.	3.0[2]
C = Sheep inventory, as of Mar. 31, million head.	5.4[3]
D = Hog inventory, as of Mar. 31, million head.	256.2[4]
E = Poultry slaughtered for human consumption, dressed weight, 1,000 tons, July-June years.	1.0
F = Egg production, commercial, million dozen, July-June years (excluding Tasmania).	1.0

[1] Approximate per unit annual major grain consumption in kilograms.

[2] It is assumed that dairy cattle are fed only token amounts during certain periods of the reproductive cycle.

[3] It is assumed that only about one-tenth of the sheep are fed grain. An adequate supply of oats per sheep was estimated at 18 kilograms per head.

[4] It is assumed that swine are fed in pastures and require only one-half as much grain as U.S. grain-fed hogs.

Data Sources

Australian Bureau of Statistics

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Bureau of Agricultural Economics

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New South Wales Department of Agriculture

Weekly Marketing Notes, various issues.

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[2] It is assumed that dairy cattle are fed only token amounts during certain periods of the reproductive cycle.

[3] It is assumed that only about one-tenth of the sheep are fed grain. An adequate supply of oats per sheep was estimated at 18 kilograms per head.

[4] It is assumed that swine are fed in pastures and require only one-half as much gain as U.S. grain-fed hogs.

APPENDIX III – DATA USED IN REGRESSION ANALYSIS[1]

Year	Quantity consumed as feed[2]				
	Wheat	Barley	Sorghum	Oats	Corn
			1,000 metric tons		
1960/61	582	252	223	670	136
1961/62	469	206	234	418	150
1962/63	398	284	215	593	143
1963/64	407	193	193	519	130
1964/65	934	406	193	616	128
1965/66	705	352	272	491	90
1966/67	579	535	267	1,047	149
1967/68	737	308	329	298	139
1968/69	629	662	214	901	134
1969/70	654	551	484	797	144
1970/71	812	595	780	874	142
1971/72	970	769	223	808	124
1972/73	1,556	540	283	497	79
1973/74	1,369	642	419	762	84
1974/75	1,394	334	187	458	51
1975/76	937	695	0	645	66

Footnotes at end of table. Continued–

APPENDIX III – DATA USED IN REGRESSION ANALYSIS[1]

Continued

Year	Price as feed[2]				
	Wheat	Barley	Sorghum	Oats	Corn
	Dollars per metric ton				
1960/61	56.34	32.06	31.27	48.23	76.51
1961/62	58.18	42.36	31.45	56.05	58.27
1962/63	58.64	39.96	21.70	57.32	60.42
1963/64	53.58	40.17	27.88	55.13	67.53
1964/65	53.89	40.78	29.18	72.22	66.89
1965/66	56.22	44.63	28.01	74.87	83.30
1966/67	57.50	42.83	27.28	59.19	62.60
1967/68	60.81	43.11	31.91	75.61	61.22
1968/69	62.83	34.53	27.40	54.49	69.13
1969/70	52.73	29.94	36.75	34.12	54.43
1970/71	53.28	42.15	28.87	36.47	52.06
1971/72	54.75	35.01	43.19	45.10	50.98
1972/73	56.97	52.60	40.38	62.88	58.46
1973/74	71.10	59.39	63.69	61.39	86.52
1974/75	83.40	75.05	70.65	65.97	87.39
1975/76	99.06	77.80	78.53	69.83	98.54

Footnotes at end of table.

Continued—

APPENDIX III – DATA USED IN REGRESSION ANALYSIS[1]

Continued

Year	Price of substitute grains for:[2]				
	Wheat	Barley	Sorghum	Oats	Corn
	Dollars per metric ton				
1960/61	47.68	49.00	53.03	51.31	49.11
1961/62	50.47	44.76	52.52	51.57	49.19
1962/63	53.36	51.24	55.60	54.05	50.99
1963/64	60.96	48.78	54.53	50.11	50.01
1964/65	60.96	49.52	55.90	53.07	51.61
1965/66	62.16	52.01	66.03	54.18	60.21
1966/67	53.68	50.82	56.49	53.08	52.08
1967/68	61.74	54.51	63.86	55.50	59.73
1968/69	50.76	53.00	58.01	54.59	53.81
1969/70	35.77	44.82	47.55	44.03	45.21
1970/71	40.26	45.17	44.10	47.66	41.10
1971/72	42.30	43.49	46.24	46.68	45.01
1972/73	59.00	56.15	57.49	56.46	54.81
1973/74	64.07	67.96	63.95	68.33	62.51
1974/75	72.51	76.15	70.14	80.12	69.14
1975/76	77.16	85.57	80.11	90.01	78.74

Footnotes at end of table. Continued–

APPENDIX III – DATA USED IN REGRESSION ANALYSIS[1]

Continued

Year	Livestock	
	Price[3]	Inventory
	Index	Million units
1960/61	103	1,407
1961/62	97	1,453
1962/63	102	1,490
1963/64	104	1,448
1964/65	98	1,508
1965/66	99	1,601
1966/67	101	1,579
1967/68	98	1,650
1968/69	94	1,741
1969/70	96	1,859
1970/71	95	1,964
1971/72	92	2,021
1972/73	97	2,088
1973/74	133	1,990
1974/75	152	1,848
1975/76	159	1,811

[1] See app. II for detailed descriptions of the variables.

[2] All data for wheat, barley, and oats are on a December-November year; data for sorghum and corn are for an April-March year.

[3] July-June year, 1960/61-62/63 = 100.

APPENDIX IV – CORRELATION MATRIXES

Commodity	Own price X_{1_i}	Price of substitutes X_{2_i}	Livestock price, X_3	Livestock inventory, X_4
Wheat				
Y_w	-0.246	0.153	0.326	0.731
X_{1_w}		0.440	0.036	-0.168
X_{2_w}			0.453	0.338
X_3				-0.070
Barley				
Y_b	0.154	-0.389	-0.360	0.819
X_{1_b}		0.501	0.598	0.157
X_{2_b}			0.349	-0.411
X_3				-0.070
Sorghum				
Y_s	0.065	-0.502	-0.344	0.501
X_{1_s}		-0.372	-0.569	0.693
X_{2_s}			0.360	-0.396
X_3				-0.751
Oats				
Y_o	-0.582	-0.412	-0.368	0.284
X_{1_o}		0.826	0.325	-0.364
X_{2_o}			0.527	-0.262
X_3				-0.070
Corn				
Y_c	-0.333	-0.466	0.093	-0.394
X_{1_c}		0.619	0.521	-0.588
X_{2_c}			0.260	-0.273
X_3				-0.751

APPENDIX V – ESTIMATED REGRESSION COEFFICIENTS AND STATISTICS

Wheat:

n	Constant	Own price	Price of substitutes	Livestock prices	Livestock inventory	$S.E.$	$C.V.$	$D.W.$	$\bar{R}^2$
13	-1452.76	-0.36448 (0.173)	0.20296 (0.073)	11.7093 (11.4)	1.21103 (0.209)	159.6	22.1	1.750	0.7666
14	-460.648	-0.43311 (0.141)	0.22532 (0.065)	4.65877 (5.820)	1.1978 (0.203)	155.4	21.5	1.527	.7664
15	-1120.61	-0.31145 (0.136)	0.20512 (0.070)	6.23752 (6.344)	1.1472 (0.222)	171.3	23.7	2.097	.7089
16	-1349.24	-0.21748 (0.093)	0.19594 (0.069)	3.78937 (5.778)	1.1382 (0.221)	170.6	23.6	1.982	.6906
Mean (14-16)	-976.833	-0.32068	0.20879	4.8952	1.611	–	–	–	–

Note: Numbers in parentheses represent estimated standard errors of the coefficients.

APPENDIX V – ESTIMATED REGRESSION COEFFICIENTS AND STATISTICS

Barley:

n	Constant	Own price	Price of substitutes	Livestock prices	Livestock inventory	$S.E.$	$C.V.$	$D.W.$	$\bar{R}^2$
13	4.4220	-0.09035 (0.076)	0.05607 (0.060)	-7.7287 (8.07)	0.74084 (0.158)	101.8	23.4	3.329	0.6996
13	-673.34	-0.13025 (0.064)	0.05950 (0.060)	–	0.77172 (0.154)	101.4	23.3	3.000	0.7024
14	-946.892	-0.12306 (0.075)	0.06533 (0.062)	1.7047 (3.98)	0.79937 (0.158)	106.4	24.4	3.158	0.6780
15	-248.73	0.02495 (0.078)	-0.02491 (0.068)	-3.4123 (4.20)	0.63508 (0.206)	116.4	21.8	3.249	0.5933
16	-1235.6	-0.12744 (0.083)	0.10069 (0.069)	2.5153 (4.40)	0.81451 (0.178)	122.7	28.2	2.760	0.5713
Mean (14-16)	-1091.25	-0.12525	0.0830	2.1100	0.80695	–	–	–	–

Note: Numbers in parentheses represent estimated standard errors of the coefficients.

APPENDIX V – ESTIMATED REGRESSION COEFFICIENTS AND STATISTICS

Sorghum:

n	Constant	Own price	Price of substitutes	Livestock prices	Livestock inventory	Dummy variable	$S.E.$	$C.V.$	$D.W.$	$\overline{R}^2$
13	178.61	−0.17275 (0.092)	−0.10731 (0.064)	3.1346 (16.4)	0.56177 (0.285)	–	132.9	44.2	2.490	0.3394
13	538.65	−0.17430 (0.087)	−0.10621 (0.060)	–	0.52982 (0.219)	–	125.6	41.8	2.554	0.4101
13	-249.849	−0.15144 (0.095)	–	–	0.60962 (0.236)	–	138.4	46.0	1.981	0.2837
13	83.4056	−0.07517 (0.051)	–	–	0.23805 (0.141)	340.261 (64.0)	71.7	23.8	2.386	0.8079
14	24.286	−0.01965 (0.032)	–	–	0.09916 (0.147)	353.72 (74.8)	84.2	28.0	2.750	0.7242
15	-9.6546	−0.00851 (0.022)	–		0.17323 (0.136)	338.50 (75.1)	85.8	28.5	2.786	0.7039
16	-69.053	−0.03702	–	–	0.26503 (0.143)	315.98 (82.6)	95.5	31.8	2.266	0.6839

Note: Numbers in parenthesis represent estimated standard errors of the coefficients.

APPENDIX V – ESTIMATED REGRESSION COEFFICIENTS AND STATISTICS

Oats:

n	Constant	Own price	Price of substitutes	Livestock prices	Livestock inventory	Oat production	$S.E.$	$C.V.$	$D.W.$	$\bar{R}^2$
13	1422.6	−0.01386 (0.082)	0.28804 (0.316)	−16.157 (14.9)	0.07505 (0.263)	–	198.8	30.3	2.539	0.1611
13	578.37	−0.11923 (0.081)	0.12245 (0.279)	–	0.06888 (0.265)	–	200.7	30.6	2.375	0.1452
13	476.975	−0.12307 (0.100)	–	–	0.38469 (0.279)	–	212.3	32.4	2.882	0.0431
13	252.65	−0.04040 (0.021)	–	–	–	0.49740 (0.078)	86.1	13.1	1.022	0.8428
14	272.21	−0.03763 (0.024)	–	–	–	0.48112 (0.092)	101.4	15.3	0.771	0.7680
15	275.14	−0.03742 (0.023)	–	–	–	0.47849 (0.085)	97.1	14.9	1.052	0.7854
16	248.46	−0.03271 (0.022)	–	–	–	0.48228 (0.084)	95.9	14.8	1.044	0.7758
Mean (13-16)	262.12	−0.03704	–	–	–	0.48482	–	–	–	–

Note: Numbers in parentheses represent estimated standard errors of the coefficients.

APPENDIX V – ESTIMATED REGRESSION COEFFICIENTS AND STATISTICS

Corn:

n	Constant	Own price	Price of substitutes	Livestock prices	Livestock inventory	Corn production	$S.E.$	$C.V.$	$D.W.$	$\bar{R}^2$
13	634.200	−0.01462 (0.006)	−0.011690 (0.009)	−1.91672 (1.68)	−0.09923 (0.027)	–	13.6	10.5	0.919	0.605
13	418.335	−0.11515 (0.007)	−0.11679 (0.009)	–	−0.7938 (0.021)	–	13.8	10.6	0.621	0.592
13	395.306	−0.01992 (0.005)	–	–	0.083165 (0.022)	–	14.2	10.9	0.951	0.570
13	178.439	−0.07687 (0.007)	–	–	–	–	21.4	16.5	0.992	0.030
13	30.292	–	–	–	–	0.5666 (0.176)	16.3	12.6	0.553	0.4372
14	13.363	–	–	–	–	0.65411 (0.171)	16.9	13.0	0.480	0.5122
15	−12.720	–	–	–	–	0.78628 (0.150)	17.7	13.6	0.553	0.6604
16	−24.386	–	–	–	–	0.85619 (0.149)	18.4	15.5	0.582	0.6807

Note: Numbers in parentheses represent estimated standard errors of the coefficients.

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